Airfields for Heavy Bombers

by Anthony F. Turhollow

The Corps of Engineers inherited a major technical challenge when the War Department in late 1940 assigned it the responsibility for constructing the air bases required by the nations land forces. The problem confronting the Corps was to build airfields capable of serving the very heavy bombers then under development, flying machines that would assume a central role in the United States' war fighting strategy.

The engineers learned the magnitude of the challenge they faced in May 1941 when the first experimental long-range bomber, an XB-19 built by the Douglas Aircraft Company at Santa Monica, California, taxied out of the company's

The 24-ton Douglas XB-19 poised for takeoff in January 1942.

hangar at nearby Clover Field. Designed to weigh 80 tons when fully loaded, the empty test plane broke through the apron to a depth of about 1 foot. Only seven weeks later, after a new concrete runway had been completed, could the aircraft make its maiden flight. Observing the plane's landing at March Field, California, engineers from the Corps' Los Angeles District reported that a depression and cracks appeared in the concrete runway where the plane had decelerated. Pointing out that weather and groundwater conditions were ideal during this test, the district engineer, Lieutenant Colonel Edwin Kelton, observed that after heavy

rains, landings by fully loaded B-19s might inflict "extreme damage" on available runways. The engineers received a respite when the XB-19's engines proved unequal to its great weight, but the B-29, a Boeing bomber of nearly equal weight, remained under development.

The XB-19 test clearly demonstrated that super bombers would require super airports for which there were few engineering guidelines. The high landing speeds, pounding vibrations, and violent propeller blasts of the new, heavy bombers would evidently require revolutionary methods of runway construction. At a minimum, the airfields designed to serve these planes would need stronger pavements, gentler grades, improved subsurface compaction, more extensive drainage structures, and better dust control. To accomplish these improvements, the engineers would have to devote, in a limited time, a considerable effort to research and experimentation.

The Air Corps had set forth rigorous requirements for air strips to accommodate around-the-clock, all-weather operations by B-19s. Runways for these bombers were to possess the following characteristics:

- Inherent strength to carry wheel loads up to 100,000 pounds.
- A stress load value of 500 pounds per square inch under impact.
- Safeguards against any weakness caused by infiltration of water into the subgrade.
- High skid resistance in wet weather.
- High visibility at night.
- A low crown, to reduce the hazard of ground looping.
- Low rolling friction.
- Freedom from loose particles.
- Durability, so that they would require no maintenance except repairs of bomb damage.

The Corps of Engineers quickly marshaled its resources and those of the nation's engineering profession to meet the requirements of the Air Corps. William McAlpine, the senior engineer who in 1941 headed the Engineering Section of the Corps' Civil Works Division, arranged for the Ohio River

Division to test the applicability to airfield construction of current concrete design principles. The Cincinnati-based division's Concrete and Soil Mechanics Laboratories, which had been organized in 1934 for the Muskingum River project, provided distinguished research talent for this inquiry.

The division conducted a series of experiments on the 7-inch reinforced concrete apron at Wright Field, Ohio, and on the 6-inch concrete surface at Langley Field, Virginia, the first built over a clay subgrade and the second over a sandy silt. Using a hydraulic jack and a bearing plate, the engineers carefully observed as they placed 60 one-ton concrete blocks, one after another, on the centers, edges, and corners of concrete slabs. At the same time, experiments in which planes landed on lime-coated runways provided better information about tire imprints. The experiments demonstrated that the classic analysis of stresses in concrete pavements developed by Harald Westergaard, dean of Harvard's Graduate School of Engineering, provided the engineers a "very, very wonderful handle," as Soils Mechanics Laboratory head Robert Philippe reported. At division headquarters, Evan Bone meanwhile developed a family of curves which would enable any engineer, once he had determined the rigidity of the subgrade, to quickly calculate the thickness of concrete required for any wheel load up to 30 tons.

While these experiments largely resolved the theoretical questions involved in the use of concrete pavement, they did not address the specifications of the asphalt runways which the Corps of Engineers hoped to build for the new, heavy bombers in distant theaters of operation from which the Americans could carry the war to the enemy homelands. Colonel James Stratton, who had supervised two large New Deal dam and reservoir projects before succeeding McAlpine as chief of the Engineering Division at Corps headquarters in December 1941, organized a series of tests to determine the subsurface compaction and pavement thickness and deflection demanded by the heavy bombers.

Fortunately, highway engineering practices provided a starting point. The advent of the automobile and truck in the first years of the 20th century had led to a demand for better roads, both asphalt and concrete. To meet this demand, state highway departments had cooperated in studies of pavement design. The federal government also promoted investigative programs, as did the Portland Cement Association and the Asphalt Institute. Because a single-engine trainer had about the same wheel load as a heavy commercial truck, early airport designers used the same criteria as highway engineers. But for very heavy bombers, these criteria were insufficient and a new methodology had to be devised.

Stratton and his staff found that the California Bearing Ratio, a series of curves relating the thickness of asphalt paving required to support various loads to the nature of the soil which underlay the pavement, provided the most promising tool for analyzing the surfaces that would be required for the new bombers. The ratio had been developed by O. James Porter, a California state highway engineer, and had up to that time been applied only to loads which might be borne by asphalt roads. But after the highly respected Harvard soils engineer Arthur Casagrande affirmed the formula's potential value for determining the appropriate thickness of runways to support heavy bomber landings on different subsurfaces, Stratton embarked on a series of experiments designed to expand and test the design curves derived from Porter's ratio.

Prominent engineers in the Corps' airfield development program observed pavement experiments at the Stockton Test Track near Sacramento, California (Front row: Colonel Henry C. Wolfe, Harald M. Westergaurd, Philip C. Rutledge. Standing on the tire: Arthur Casagrande, Thomas A. Middlebrooks, James L. Land, and O. James Porter).

Assisted by the staffs of five of the Corps' divisions, Stratton tested runway pavements built at Army airfields across the nation. The engineers towed equipment with wheel loads of 5,000 to 50,000 pounds over runways whose subsurface composition and compaction they had previously determined to calculate the limit of weight each could support. The results verified the potential of Porter's design curves to be extended to the weights and pavement thicknesses involved in surfaces that could support the new bombers. Actively participating in the studies, Porter concluded that pavements would fail if deflected more than 1/20 of an inch. However, leaders of the Air Corps' Building and Grounds Division and the Navy's Bureau of Yards and Docks remained skeptical at best, concerned that theoretical explanations had lagged behind experimental data.

In the spring of 1942, Stratton reorganized his unit, added new strength to his staff, and obtained the assistance of specialized consultants with outstanding reputations in their disciplines. With this "bunch of damn good engineers," the colonel brought his initial experiments to a productive conclusion. The concrete tests led to revisions in the curves for concrete thickness that the engineers employed in the design of rigid pavements and restricted the use of thickened edges in concrete sections. Refined concepts of flexible pavement design resulted from the tests evaluating critical deflection and the effects of repetitive loads. The studies also contributed to better understanding of material strengths, compaction methods, and curing techniques. New ideas on classifying soils, pointers on establishing and maintaining turfs, and improved methods of airfield drainage also emerged.

Corps teams digested this mass of information into three new chapters for the *Engineering Manual* and a comprehensive handbook for aviation engineer battalions issued in 1942 and 1943. A commentator in a leading engineer journal hailed the chapter on airfield drainage in the *Engineering Manual* as "a major contribution from the science of hydrology to the advancement of both civil and military aviation." Drawing upon extensive technical literature and applying the Corps' experience with flood control and river basin planning as well as the recent experiments, the chapter instructed budding airfield engineers on isohyetal maps, rainfall intensity duration curves, design storm criteria, overland flow formulas, and infiltration theories.

Despite the intensive experimentation upon which it was based, the new chapter on airfield pavements proved less authoritative. Seeking to disseminate information quickly to emerging theaters of operations, the engineers wrote before all the experimental data were available and passed hastily over some problem areas. The authors dealt with frost action on a single page, provided a somewhat rudimentary discussion of paving materials, and left unresolved some important questions relating to the design of rigid pavements. The chapter even labeled as tentative the promising design curves for base and pavement thicknesses that had emerged from the experiments. Consultants like Porter were obliged to travel continuously to address these difficult issues.

More elaborately prepared experiments conducted in 1943 at Langley Field, Virginia; Eglin Field, Florida; and Barksdale Field, Louisiana, largely confirmed the design curves that the *Engineering Manual* had labeled as tentative.

A 120-ton pneumatic roller producing firmly compacted soil.

The tests did indicate, however, that somewhat thicker bases than anticipated were required on sandy silt and black clay and that somewhat thinner ones would suffice on clean, well-drained sand. The new chief of Stratton's Airports Division, Gayle McFadden, who had directed the construction of

New York's LaGuardia Field and Washington's National Airport, kept the manual updated with the latest findings.

In August 1943, Corps districts around the United States began a series of tests of the load-bearing capacities of the runways in their regions, relying on the California Bearing Ratio curves and the plate-bearing test results for ready analysis. In the fall of 1943, as American airmen trained on the B-29s that were beginning to emerge from production lines, the engineers "beefed up" runways with asphalt overlays or additional slabs of concrete where the tests showed these were warranted.

President Roosevelt decided to deploy the B-29s initially to India and China, believing that the planes could make their most strategically significant contribution against the relatively unscathed Japanese homeland. Shortages of modern construction equipment and materials in the receiving Asian countries and a resulting reliance on large groups of laborers and more traditional materials led the engineers to conduct new tests of runways made with these supplies and methods. The Corps' Waterways Experiment Station, which had just completed a new flexible pavement laboratory, took the lead on these alternative materials tests. After overseeing a series of experiments at Marietta, Georgia, not far from the B-29 assembly plant that the Corps had built there, test director John Griffith undertook the daunting assignment of providing blueprints for the overseas very heavy bomber fields.

The Army meanwhile gave some civilian Corps soil experts direct commissions as senior officers and sent them to China and the Pacific to help build airfields prepared to handle the new B-29s. It was from the former fields that the Air Corps' Superfortresses, boasting a range of 3,250 miles, began in June 1944 the bombing raids against Japan that ended the immunity from attack previously enjoyed by the Japanese home islands. In 1945, Army engineers built B-29 fields on Saipan and Guam in the Mariana Islands from which the American bombers attacked Japan from still closer range. The Asian and Pacific fields successfully bore the demands of the new aircraft, each of which when fully loaded weighed 70 tons, more than the heaviest tank employed by the U.S. Army in the war and double the weight of the Sherman tank, the armored forces' workhorse.

Under the stress of war, the engineers attained for the United States effective world leadership in airfield design. The Corps' research effort yielded advances in engineering knowledge that won broad professional acclaim when published in the *Proceedings of the American Society of Civil Engineers.* The *National Aeronautics* journal commended the findings to "civilians planning the large commercial airports of the future." Militarily, the wartime airfield research program left the United States prepared to meet the needs of its most advanced aircraft wherever around the world the demands of the final years of World War II and the ensuing strategic competition with the Soviet Union required their deployment.

Sources for Further Reading

The chapter on "Airfields for Very Heavy Bombers" in a book by Lenore Fine and Jesse Remington, *The Corps of Engineers: Construction in the United States* (Washington, 1972), provides a well-written and detailed study of the Corps' wartime airfield research and development effort.

Other related readings include an article by Major General Henry H. Arnold, "The Air Forces and Military Engineers," in *Military Engineer,* 33 (1941): 545–548; two chapters on aviation engineers in Volume 7, *Services Around the World* (Chicago, 1958), of W. F. Craven and J. L. Cate, *The Army Air Forces in World War II*; and "Military Airfields, A Symposium," *Proceedings of the American Society of Civil Engineers,* 70 (1944): 27–89.